Communication

Activity I: How Does a Radio Work?

introduction

Introduction

The Communication section investigates how radios work. Specifically, how tuning a radio to receive a new frequency is related to the position of the antennae, capacitor, and inductor. The activity **How Does a Radio Work?** is broken up into 4 parts. **Part A. The Importance of Parallel and Perpendicular Orientation In Reception** employs knowledge about perpendicular and parallel planes and lines, as well as linear and circular equations, to teach how antennae position is important. A small statistics section, **Part B. Probability and Reception**, looks at the probability of getting ideal reception per unit time when gradually turning a circular TV or radio antennae. In **Part C. Understanding the Relationships Between Frequency, Capacitance, and Inductance,** students use algebra with radicals and pi to understand that the positions of the capacitor and inductor influence the frequency that a radio will receive and transmit. In **Part D. Understanding Components of Waves,** the main characteristics of a wave are covered, and students are urged to use their graphing calculators to discover how elements of wave equations are related to structural elements of waves.

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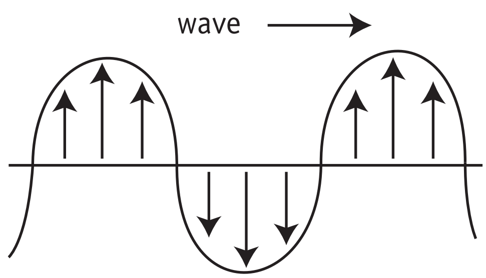
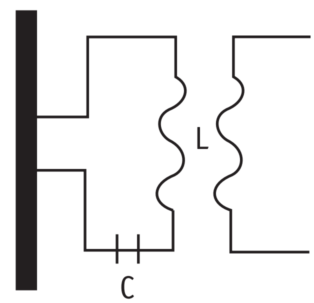
When sound is passed from one location (where it originates) to another, it is sent in the form of waves. These waves reach receiving antennae and interact with the electric charges in the antennae wires. The sound waves have electric and magnetic fields that can interact with the wires.

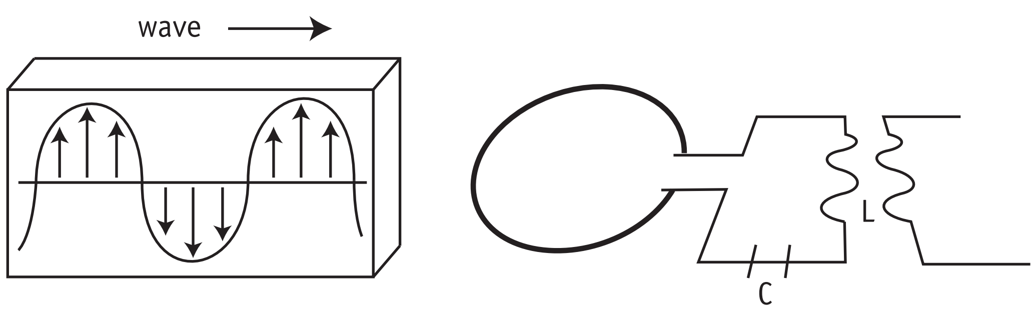
In order for the electric field to interact with the wires, the wires must be parallel to the field. The electric field acts on the electrons in the receiving wire, and by doing so an Alternating Current is generated.





Electric Field direction is parallel to receiving wires

In order for the magnetic field to interact with the receiving wires, the receiving wires must be in a loop. For best reception, the plane of the loop is oriented perpendicular to the plane of the magnetic field. This way the loop cuts through the magnetic field. As the magnetic field comes in contact with the loop, magnetic flux is altered, inducing a voltage and current in the loop, in accordance with Faraday's law.



Magnetic Field is parallel to normal of antenna loop's plane

In order to selectively limit the frequency (f_o) of waves received by antennae, the variable capacitor (C) and inductor (L) can be altered. In radios, generally the inductor is fixed, and turning a knob changes the capacitor. Dozens of radio frequencies come in contact with a single antenna, but only the radio frequency ("resonance frequency") matching the frequency to which the antenna is set will be result in good reception because this frequency will produce the most current in the antenna.

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Part A - The importance of parallel and perpendicular orientation in reception

Let us assume that no reception will take place if the proper parallel or perpendicular orientation does not occur.

1. If the plane of the electric field moves along a line of the equation $y = 2x + 3$, what do we know about the slope of the receiving wires?

2. If the receiving wires contain the point (3 , 7), what is the equation for the line that contains the receiving wires?

3. If the magnetic field moves along a plane with a slope of -2, what do we know about the slope of the receiving loop's diameter?

4. If the receiving loop's diameter contains the point (5 ,7), what is the equation for a line that contains this diameter?

5. If (5 ,7) is the center of the circle with a radius of 10, what is the equation for the loop (assume it is a full circle)?

6. At what two points do the loop and magnetic field cross if it passes through the center of the circlular loop?

Now let us assume that the receiving loop does not have to be perpendicular to the linear path that the magnetic field travels along. (You probably recall that when adjusting an antennae on a TV, the loop can be truned away from a signal, yet some signal is still received!) The amount of signal received, however, is still directly related to the angle between the magnetic field's plane of travel and the loop's plane. Although the amount of signal will vary quite a bit, for simplicity's sake, let us say that at the following angles, you receive the following percent of signal. See the chart below.

Orientation and Signal

Angle Between Two Planes (degrees)	Percent of Signal Received
90	100
85	94.44
70	77.78
60	66.67
45	50
30	33.33
25	27.78
18	20
10	11.11
0	0

7. Draw this relationship using a line graph. Let angle be x, and signal be y.

8. What is an equation that describes how the percent signal received is related to the angle between the planes?

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Part B - Probability and Reception

This section requires use of the chart from PartA.

For questions 1 to 6, the receiver can only be turned within the ranges for a, b, and c. (Hint: To make things easier, do 1 – 5 under the parameters for "a" first, then move on to "b" and "c".)

a. You may assume 0 = no signal and 90 = full signal.
b. You may assume 0 = no signal, 90 = full signal, and 180 = no signal.
c. You may assume 0 and 180 = no signal, and 90 and 270 = full signal.

1. What is the probability that you will receive a signal of 75% or greater if you randomly pick an angle to turn the receiver at?

2. If you randomly turn the receiver once every minute, on average, how long will it take for you to receive 100% signal?

3. If a person keeps turning the receiver once every minute and does not duplicate negative (<75%) signal angles, how long until the person will receive 100% signal?

4. Luckily, once people see a signal, they don't keep turning the receiver randomly. Instead, once the person gets a positive signal, that person keeps turning it in a more positive direction. If a person keeps moving the receiver once every minute and keeps turning the receiver in the positive direction, and the person can only move it 5 degrees at a time, how long until (s)he reaches 100%?

5. Which situation is most realistic for a person adjusting their TV? Explain.

Part C - Understanding the Relationship Between Frequency, Capacitance, and Inductance

As soon as the electric field comes in contact with the receiving wire, the wire is "activated" and an electrical impulse is sent across the receiving wire through other wires, finally reaching the radio, where it results in sound. The frequency (f_o) of the sound received depends on the variable capacitor (C) and the inductor (L), as described previously.

The exact relationship between these variables is defined by the following equation:

$$f_o = \frac{1}{2\pi((LC)^{1/2})}$$

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1. Fill in the following chart, showing that you understand the relationship between these variables.

Frequency, Capacitance, and Inductance

Frequency (kilocycles/second)	Capacitance (C)	Inductance (L)
30	2.50×10^{-4}	
30	1.00×10^{-4}	
30		5.00×10^{-12}
30		1.00×10^{-11}
3,000	5.00×10^{-4}	
3,000	1.00×10^{-4}	
3,000		2.50×10^{-9}
3,000		3.00×10^{-9}
30,000	15.00	
30,000	20.00	
30,000		25.00
30,000		30.00
300,000	2.00×10^{-14}	
300,000	4.00×10^{-14}	
300,000		6.00×10^{-4}
300,000		8.00×10^{-4}

2. As the capacitor and inductor values get smaller, the frequency values get ______________.

   Cite example(s):

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3. For a single frequency, as the capacitor value gets smaller, the inductor value gets _____________.
   Cite example(s):

4. As the product of inductor and capacitor values grows, the frequency gets _____________.
   Cite example(s):

5. If the capacitor value is 10×10^{-12} and the indicator value is 30×10^{-4}, the frequency is ______________________________________.

6. If the inductor value is 10×10^{-12} and the capacitor value is 30×10^{-4}, the frequency is _____________________.

7. What do you notice about inductor, capacitor, and frequency settings in #5 and #6?

Some common/familiar frequencies are listed in the following table.

Common Radio Frequencies

Frequency (kc or kHz)	Common Use
535– 1,605	AM radio
88,000– 108,000	FM radio
54,000– 88,000	TV channels 2– 6
174,000– 216,000	TV channels 7– 13
3,000– 30,000	Ship-to-ship and ship-to-shore communication
30,000– 300,000	Very High Frequency (VHF): aircraft-to-aircraft and air navigation, some TV
300,000– 3,000,000	Ultra High Frequency (UHF): some TV transmission

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8. Based on what you see in the Common Radio Frequencies chart, why do you think airline attendants ask passengers to turn off electronic devices including phones, radios, TVs, and computers during take-off and landing?

9. If you wanted to set your radio's receiving end for the following uses, to what would you set the different components?

Radio Communications

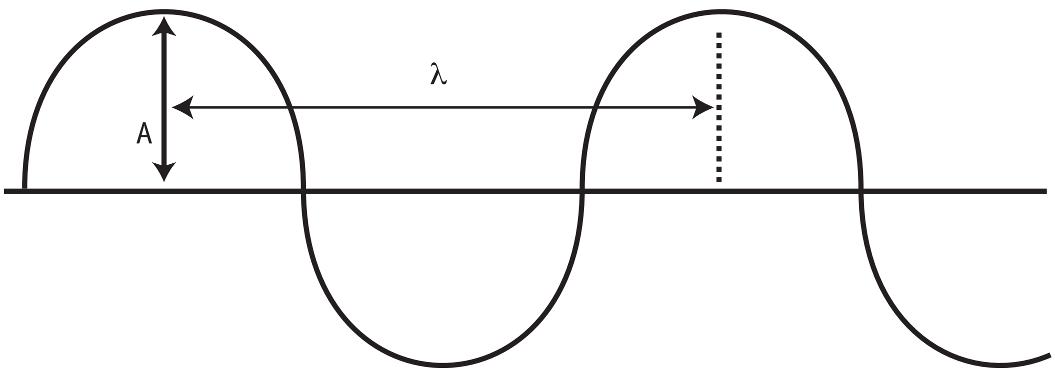
Use	Frequency	Inductance (L)	Capacitance (C)
Popular AM News Radio Station	740 kHz	5.00×10^{-4}	
Popular FM News Radio Station	104.9 MHz or 104900 kHz		2.30×10^{-11}
Your favorite radio station		3.50×10^{-5}	
Communication between a lighthouse and a fishing boat		7.00×10^{-6}	5.79×10^{-12}
TWA #218 to San Francisco International Airport		4.00×10^{-7}	8.96×10^{-13}

Part D - Understanding Components of Waves

Frequencies also have to do with some physical characteristics of the waves. Based on what you have done above, you now know how to alter radios so they can receive certain frequencies. But how can the provider of the sound change their frequencies? To understand this, we need to know something about waves.

Waves have 5 main characteristics:

- Frequency (f_0)= # of cycles / unit time
- Amplitude (A)= 1/2 distance between maximal and minimum values obtained by function.
- Wavelength (λ)= horizontal length of one cycle of wave
- Period (T) = time required for one cycle of wave to move past a given point / observer. Reciprocal of frequency.
- Phase Shift = least positive or greatest negative horizontal translation that maps sin x or cos x onto the given wave; delay in time when sine or cosine happens, as if it were to start at origin.



In math, there are several wave types easily defined by trigonometric equations. For instance, sine and cosine make beautiful waves, commonly referred to in science, technology, and math fields. The sine wave is also known as a wave representing pure tone.

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Use a graphing calculator to see which of the 5 characteristics of waves are controlled by the following variables. Do this by entering the following equations one-by-one and writing what you observe about them with respect to the first equation, $y = \sin x$.

1. $y = \sin x$ Sketch:

2. $y = \sin 2x$ Observation: ____
Sketch:

3. $y = 2\sin x$ Observation: ____
Sketch:

4. $y = \sin x + 2$ Observation: ____

Sketch:

5. $y = \sin(x + 2)$ Observation: ____

Sketch:

6. $y = (^1/_2)\sin x$ Observation: ____

Sketch:

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7. n $y = \sin(x/2)$ Observation: ___________________________________
 Sketch:

8. $y = 2/(\sin x)$ Observation: ___________________________________
 Sketch:

9. In the sine equations #2 to #5, replace all twos with negative twos, and observe the changes. Mark the new graphs on your previous sketches, in a different color.

10. For the equation $y = a\sin(bx + c) + d$,

a changes ________________, b changes ______________________________,

c changes ______________________, and d changes _________________.

11. How was use of fractions to investigate especially helpful to clarify the influence of b on the equation?

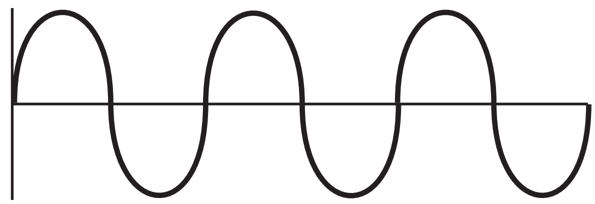
12. What happens when a or b are made negative?

13. What did negative c and d show you?

The following waves are produced by a variety of instruments, all creating the A note. Approximate the equations for each frequency, using what you now know about sine waves and your graphing calculator.

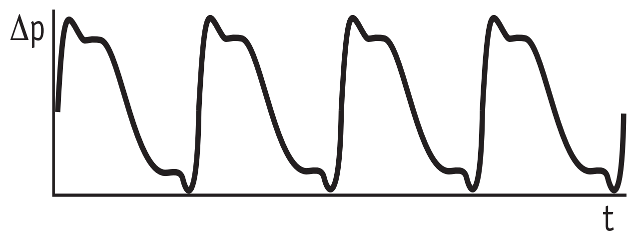
14. Pure Tone (Tuning Fork) wave form:

y = ____________

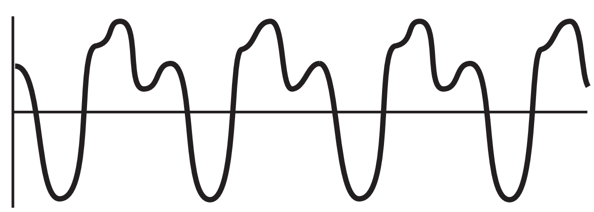


15. Piano wave form:

y = ____________



16. Flute wave form:

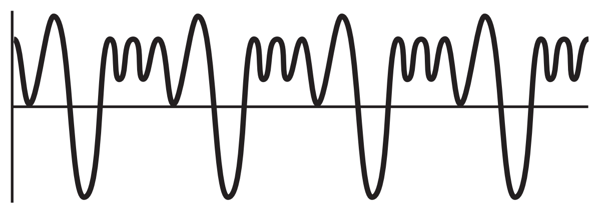


y = ____________________________________

17. Clarinet wave form:

y = ____

18. Trumpet wave form:



y = ____

19. Violin wave form:

y = ____